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The effects of noise from combined traffic sources on annoyance: the case of interactions between rail and road noise

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ABSTRACT

The combination of rail and road (highway, main roads) noise exposure is highly prevalent in European countries. In Germany, the number of people exposed to both were estimated to be around 11 millions. Although increasing consideration has been given to the effects of noise from combined traffic sources at conferences during the last decade (Internoise 1996, 1997, 2000, 2001, 2006) the scientific community still lacks a full understanding of this issue. Its proper understanding is, however, important for regulatory purposes. Therefore, it is not surprising that in current practice the community response to noise is assessed source by source.

In 2006, a socio-acoustic survey (N=1643) was repeated in the same alpine valley with the same questionnaire as in 1998 (N= 2007). Thus, we were able to evaluate and extend our earlier analyses.

Results: Annoyance due to rail noise is significantly modified through additional highway or main road noise. This modifying effect takes preferably place beyond 300m from the rail track. Overall, when the rail exposure is significantly higher (>6dBA) than the highway noise the combined effect is strongest. Finally, the exposure pattern observed in this survey (alpine valley) differs substantially from the exposure pattern seen in a large survey (N=7500) in Flandern (plain area).

1 INTRODUCTION

In a paper given at Internoise 2001, Job & Hatfield [1] perfectly summarize the issue at stake: „Our understanding of the effects of noise from combined sources on reaction, and other potential consequences of noise exposure (e.g. sleep disturbance, cardiovascular disease), is inadequate, despite an array of theories and data pertaining to this issue. .. Nonetheless, understanding the interactive effects of noise from combined sources is critical to effective regulation“. Although increasing consideration has been given to the effects of noise from combined traffic sources at conferences during the last decade (Internoise 1996, 1997, 2000, 2001, 2006) the scientific community still lacks a full understanding of this issue. Therefore, it is not surprising that in current practice the community response to noise is assessed source by source, although proposals to handle mixed source assessment are available [2,3,4,5,6,7,8,9,10,11,12,13,14]. It is silently assumed that the single standard exposure-response curves accommodate also for mixed exposures. Theoretically, one would expect deviations in reactions in both directions, depending on the nature of the source. A continuous source (like a highway) could mask other sources if some of the frequency range overlaps. On the other hand, there are good reasons to assume that an intermittent source (like rail or aircraft) which has a different frequency spectrum, additional tonal components, vibrations or non-acoustical features (e.g. air pollution) may increase the reactions of the concerned population due to additional interfering sensory information input.

2 METHODS

2.1 Area, sample selection and recruitment

The area of investigation, the Unterinntal, is the most important access route for heavy goods traffic over the Brenner. The goods traffic over the Brenner has tripled within the last 25 years and the fraction of goods moved on the road has substantially increased (up to 2/3). The area consist of small towns and villages with a mix of industrial, small business and agricultural activities. The primary noise sources are highway and rail traffic. Other sources are a main road, which links the villages and access roads to the highway.

People were contacted by phone based on a stratified, random sampling strategy. The address base was stratified by use of the GIS (Geographic information system), based on fixed distances to the major traffic sources (rail, highway, main road), leaving a common „background area“ outside major traffic activities and an area with exposure to more than one traffic source “mixed traffic”. From these five areas households were randomly selected and replaced in case of non-participation. Selection criteria for people were age between 25 and 75 years, sufficient hearing and language proficiency. An exclusion criterion was duration of living less than one year at this address. 45% did not want to participate. The rest of the addresses were not valid (commercial etc), did not have telephone or could not be reached by 3 attempts at different times of the day. Eventually, 1643 persons (35 % of the original sample on an individual basis), participated in this study. On household level the participation was much higher. Women were much more willing to participate (61%).

2.2 Noise exposure assessment

Three groups of traffic noise sources are considered in the noise exposure assessment: highway road traffic, road traffic on main roads, and railway traffic. For highway traffic the yearly average load (light and heavy vehicles) is combined with an average diurnal traffic pattern. Existing traffic intensity data on main roads are supplemented with additional counting to complement the source picture. Noise emission by road traffic is calculated on the basis of the Harmonoise source model [15]. Railway noise emission is extracted from a typical day of noise immission measurements at close distance to the source. Sound propagation is modeled using an extended version of ISO9613. The model includes up to four reflections and two sideway diffractions.

An extensive noise monitoring campaign was conducted to check the validity of these simulations. At 38 location sound levels were recorded for over one week during winter (October to January) and during summer (June to August). These measurements revealed a small underestimate in the noise level calculations for locations at (slightly) elevated altitude along the valley slopes. Inside villages, the model is know to underestimate slightly the level at the most exposed facade and to overestimate the level at the quiet side.

Indicators of day, evening, night exposure and Lden were calculated for each source and total exposure at several points on the facade of the building of the survey participants.. In the presented analyses Lden of the respective sources was utilized..

2.3 Questionnaire information

The questionnaire covered socio-demographic data, housing, satisfaction with the environment, general noise annoyance, attitudes toward transportation, interference of activities, coping with noise, occupational exposures, lifestyles, dispositions such as noise and weather sensitivity, health status, selected types of illnesses and medications. The phone interview took about 15-20 minutes to complete.

Noise annoyance was measured with a 5-point verbal scale according to ICBEN and ISO standards [16,17]. In the present analyses, highly annoyed was defined by responses to the two upper points (4+5) on the 5-point verbal scale.

2.4 Statistical analysis

Exposure-effect curves were calculated with extended logistic regression methods using restricted cubic spine functions to accommodate for non-linear components in the fit if appropriate [18]. The non-parametric regression estimate and its 95% confidence intervals are based on smoothing the binary responses and taking the logit transformation of the smoothed estimates. The analysis was carried out with R version 2.4.1 [19] using the contributed packages “Design” and “Hmisc” from F Harrell.

3 RESULTS

3.1 Noise exposure by sampling categories

Stratifying the overall (total) noise exposure by the traffic – sampling categories indicates highest mean noise exposure produced by single rail traffic and not by mixed source exposure (Fig 1). The mixed exposure reveals, however, the largest spread, which is mainly due to the different possible combinations and the small sample (N=49). Highway and main road together do not sum up to very high values and people living along main roads in the second or third row are usually better shielded from exposure by building structures as are residents living along the railway line or the highway. A bit surprising also the relative high “background” exposure in the rural areas which lie outside the main traffic lines.

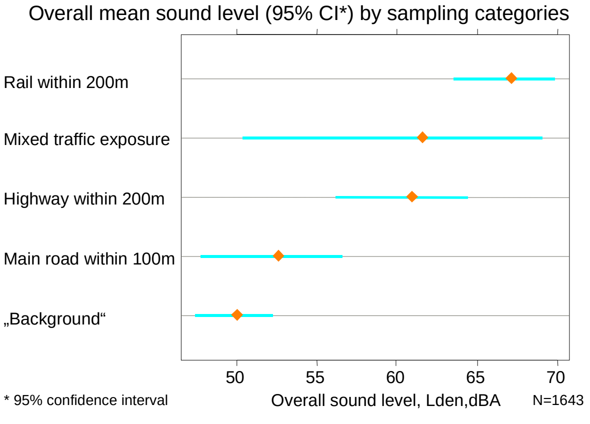

Figure 1. Mean sound level, Lden, dBA by traffic source survey sampling categories

3.2 Correlation between traffic sources

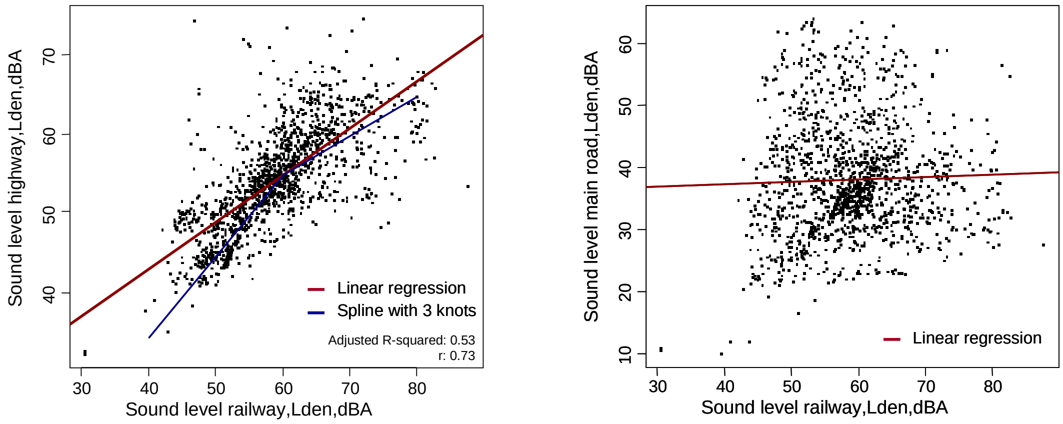

Figure 2. Correlation between railway sound levels and highway (left) and main road (right)

Due to the limited space in the bottom of the valley and the fixed space by residential areas, not much room is left for traffic infrastructure. Therefore, a strong correlation between highway and railway lines (Fig 2) exists, while the main road linking the communities is further away and does not show any correlation to the other traffic lines.

3.3 Railway noise exposure-annoyance by highway sound exposure

Exposure-annoyance curves for railway are shown by 3-levels of highway exposure (Figure 3a) or by 4-difference levels between rail and highway (Figure 3b). Around 60 dBA,Lden rail noise exposure annoyance lines cross: higher rail exposure is more annoying when road exposure is low. The lowest exposure-annoyance curves result when the difference between rail and highway noise exposure is between 0 and 6 dBA. When highway noise is larger (diff <=0 dBA) a parallel shift to overall higher annoyance is observed. When rail dominates by more than 6 dBA the curve starts with lower annoyance but exceeds the highway annoyance curve at higher rail sound levels.

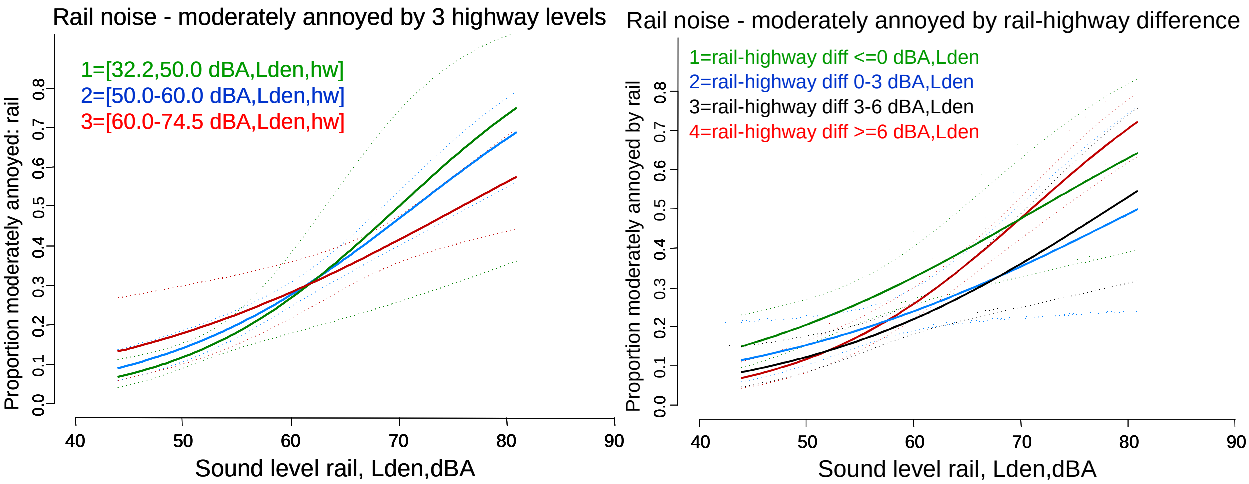

Figure 3. Exposure-annoyance curves for railway noise by 3 levels of highway exposure (Figure 3, left) or by 4 levels of difference between rail and highway (Figure 3, right).

3.4 Railway noise exposure-annoyance by distance: overall assessment

As we have shown deviating exposure response curves in alpine areas we also tested the relationships by distance and adjusted for the presence of the other source (highway or main road exposure). While within 300 m of the rail track we do not see a difference in annoyance, when another source is present, there is a significant upward trend in annoyance beyond 300 m, when another source is present.

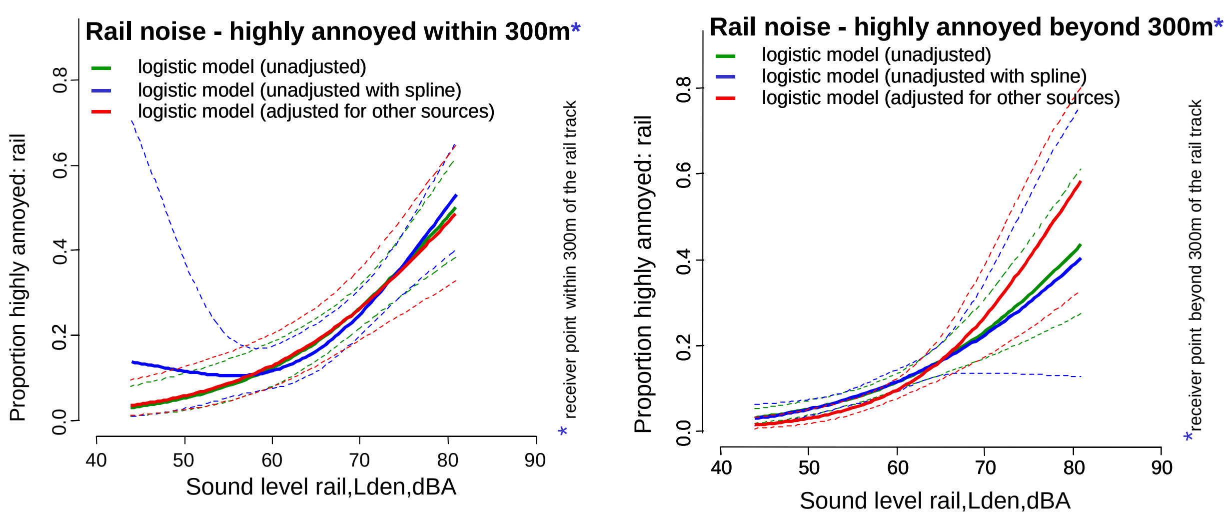

Figure 4. Exposure-annoyance curves for railway noise in the presence of other sources of road noise near (within 300m, left) and far (beyond 300m, right) from the rail track.

3.5 Railway noise exposure-annoyance by distance: specific assessment

Following up on the results reported in Figure 4 we specifically tested for the situation of the combined road noise exposure beyond 300m from the rail. In both cases (Figure 5) you can observe a higher exposure-annoyance curve when road sources show lower exposure levels and less annoyance when road sources are louder.

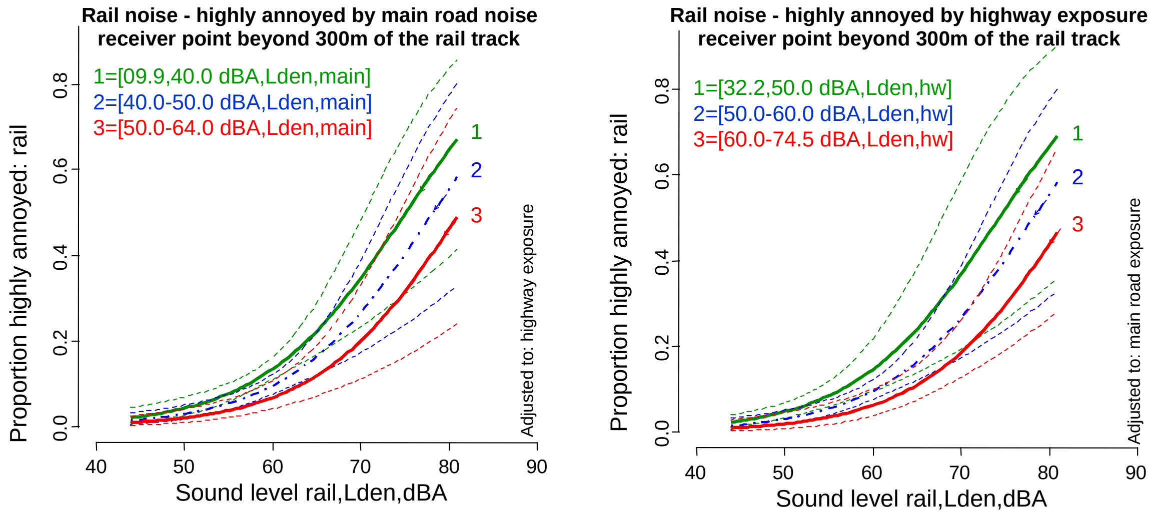

Figure 5. Exposure-annoyance curves for railway noise by 3 levels of additional road noise exposure (main road, left and highway, right).

3.6 Railway noise exposure-annoyance by distance: comparison with a experimental and a field survey in Flandern

In Figure 4 exposure-annoyance curves did not significantly differ for people living within 300m of the rail track or beyond 300m. This clearly represents a deviation from typical situations as shown in Figure 6. In both data sets the exposure-annoyance curve does show a difference in response depending on distance from the rail track.

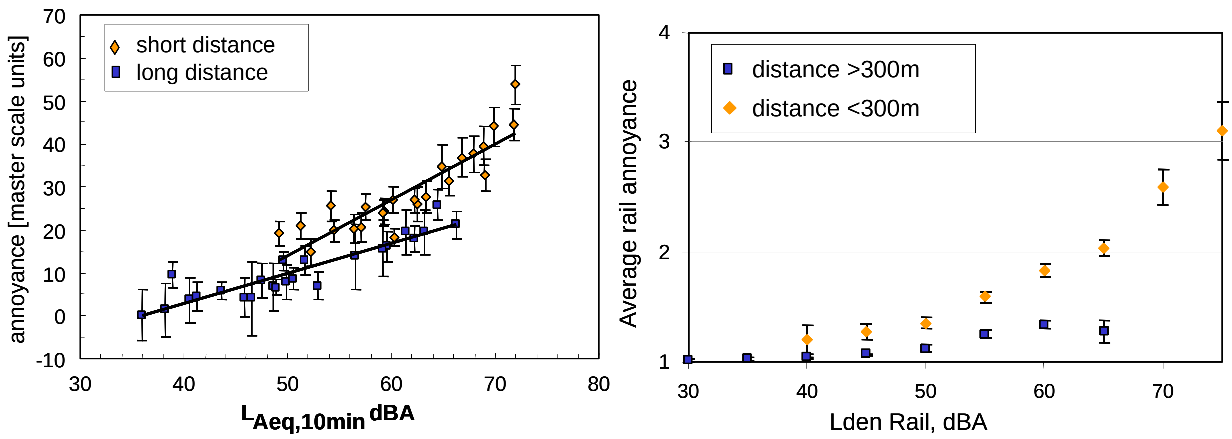

Figure 6. Exposure-annoyance curves for railway noise from a experimental setting (left) and from a large field survey in Flanders.

4 DISCUSSION

The results obtained with a large survey (N=1643) in an alpine valley do provide additional input to what is known in the literature [20,21,22,23] about the annoyance response to rail noise when exposure to more than one noise source is concerend. With a broader analysis framework it was possible to approach the question of combined exposure from different angles. As the stratified results with respect to the source sampling (Figure 1) have shown – the mixed exposure does not necessarily mean higher annoyance. Complex masking processes seem to reduce rail annoyance when road levels are higher, however, as Figures 3 and 5 have revealed, in case of lower levels of road traffic exposure the opposite can occur. This was reported from careful experimental studies [11] and is important for planning and abatement. Paradox effects could occur after abatement measures or re-routing of road traffic noise.

We could repeat earlier results (Figure 3, right) which demonstrated higher annoyance by rail exposure when rail dominates by more than 6 dBA over road traffic [21]. This may have been overlooked in other analyses as difference measures were not used or larger categories had been applied (e.g. 10 dB), which were not sensitive enough to detect differences [19].

The results further show that the combined effects may occur in specific segments only (beyond 300m) or within smaller areas with specific types of combinations (low and high exposure). Eventually, the differences seen between flat areas and alpine areas should be investigated further. A true comparison is nearly impossible as the unique feature of a valley represents a different exposure opportunity, as the exposure towards the slopes will typically be underestimated [24]. The general exposure situation is also considerably different because the railway track and the highway run practically in parallel along the valley axes. This implies that the source is much more similar (same number of trains) at all survey locations. Furthermore, the change induced by noise barriers may not adequately being captured by the standard noise metric [25]. Finally, some of the results at larger distance could be replicated also in the Flandern survey [25].

5 CONCLUSIONS (OR SUMMARY)

The annoyance response due to combined exposure to more than one traffic source is still less understood. The response varies depending on the specific types of source combinations, the topographic layout of the area, noise abatement measures and more.

When road noise exposure is low rail noise annoyance is higher. Masking is a possible explanation as the opposite effect (when rail is low highway annoyance is not higher) could not be observed The silent assumption that the single standard exposure-response curves accommodate also for mixed exposures should be questioned.

The observed pattern should be considered when traffic planning and abatement measures is at stake.

The comparison between the rail noise exposure – annoyance curves in a flat area and in an alpine valley has revealed substantial differences, when the distance to the source is considered. The alpine exposure situation with direct exposure to the slopes deviates from the typical noise exposure propagation with larger distance [24].

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